WATER RESOURCES DEVELOPMENT PROJECT

CHARLES RIVER DAM

CHARLES RIVER BASIN, MASSACHUSETTS

DESIGN MEMORANDUM NO.9

CATHODIC PROTECTION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

APRIL 1974

31

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E 30 April 1974

SUBJECT: Charles River Dam, Charles River Basin, Massachusetts, DM No. 9, Cathodic Protection

HQDA (DAEN-CWE-B)
WASH DC 20314

1. In accordance with ER 1110-2-1150, there is submitted for review and approval, DM No. 9, Cathodic Protection, for the Charles River Dam Project.

2. The contract for construction of the Charles River Dam (except for cathodic protection) was awarded on 22 February 1974. It is proposed that the cathodic protection be added to the contract by change order.

FOR THE DIVISION ENGINEER:

Incl (10 cys)
as

JOHN Wm. LESLIE
Chief, Engineering Division

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CHARLES RIVER DAM
CHARLES RIVER BASIN
MASSACHUSETTS

Design Memoranda Index

No.	Title	Anticipated Submission Date	Date Submitted	Date Approved
1	Hydrology and Tidal Hydraulics		21 May 71	2 Aug 71
2	General Design, Site Geology and Relocations		14 Feb 72	13 Mar 72
3	Concrete Materials		19 Feb 71	29 Mar 71
4	Embankments and Foundations		22 Feb 72	15 Mar 72
5	Pumping Station and Appurtenant Structures		2 Nov 73	27 Nov 73
6	Vehicular Viaduct		28 Feb 72	15 Mar 72
7	Navigation Locks and Facilities		11 Apr 73	23 May 73
8	Cofferdams		8 Jun 72	25 Jul 72
9	Cathodic Protection		30 Apr 74	

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CHARLES RIVER BASIN, MASSACHUSETTS
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CHARLES RIVER DAM
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DESIGN MEMORANDUM NO. 9
CATHODIC PROTECTION

A. PERTINENT DATA

Purpose	To present the proposed method of corrosion protection for the Charles River Dam, locks, pumping station and fendering system.
Location	
State	Massachusetts
County	Suffolk
City	Boston
River	On the Charles River 2,250 feet downstream of the present Charles River Dam.

Navigation Lock Features

Lock Gates	Large Lock		Small Locks	
Location	Tide	Basin	Tide	Basin
Number	1 (2 leaves)	1 (2 leaves)	2 (4 leaves)	2 (4 leaves)
Interior angle ea. gate	63°- 26'	63° - 26'	63° - 26'	63°- 26'
Radius of ea. gate to outside face of skin plate	24'-0-3/4"	24'-0-3/4"	13'-5-3/8"	13'-5-3/8"
Outer circumference of each gate	26.64'	26.64'	14.89'	14.89'
Top El. (MDC Datum)	117	117	117	117
Sill El. " "	86	91	94	100
Height of ea. gate	31'	26'	23'	17'
Width of opening	40'		25'	
Operating Mechanism	Hydraulic		Hydraulic	
Lock Culvert Sluice Gates	2 @ 6' x 7'		8 @ 4' x 4'	

Lock Pump System	
Lock Pumps	2 vertical 20" Mix Flow Propeller
Operating Mechanism	Electric Motor Driven
Valves	2-20", 2-36", and 1-48" Butterfly
Pump Station	
Pumps	6 - 144" diameter vertical mix-flow propeller
Operating Mechanism	Diesel Engine
Sluice Gates	2 - 8' x 10'
Trash Racks	37' x 27' - 9"

B. INTRODUCTION

1. Purpose. - The purpose of this design memorandum is to outline the proposed methods of protecting the various steel structures of the Charles River Dam, that are immersed in water, against corrosion by the application of paint and the installation of a cathodic protection system.

2. General Description. - The Charles River Dam will be located in the City of Boston, approximately 0.7 miles upstream from the confluence of the Charles and Mystic Rivers at Boston inner harbor. The facility consists of three navigation locks, a 8,400 cfs pump station with 6 - 144 inch diameter mixed flow vertical pumps, a police patrol facility, and a fishway facility with river sluiceways. The navigation locks are provided with steel sector gates, a lock pump dewatering system, and a fendering system partially fabricated with steel piles. A general layout of the facility is shown on Plate 1.

C. INVESTIGATIONS

3. Investigations. - In connection with the design of the Charles River Dam, the Hinchman Company, Corrosion Engineers, Detroit, Michigan, contracted as consultants, investigated the extent of corrosion activity at the nearby Mystic River Locks, which are similar in design to the Charles River Project, and made recommendations for corrosion mitigation measures at the Charles River Dam. Inasmuch as their report was included in Design Memorandum No. 7, NAVIGATION LOCKS AND FACILITIES, dated April 1973, as Appendix B, it is not duplicated here. The results of the survey indicated the need for cathodic protection measures to supplement protective coatings.

D. METHODS CONSIDERED

4. Corrosion Protection Methods Considered. -

a. Five basic methods of protecting underwater surfaces of steel structures were considered as follows:

(1) Unpainted metal with cathodic protection.

(2) Application of a paint coating supplemented with cathodic protection.

(3) Application of a coal-tar epoxy paint coating supplemented with cathodic protection.

(4) Application of a coal tar epoxy paint coating without cathodic protection.

(5) Use of corrosion resisting alloy iron castings.

b. Relative merits of these are considered in the following paragraphs:

(1) Unpainted Metal with Cathodic Protection. -

Cathodic protection of bare metals in sea water can often be done very satisfactorily with the use of an impressed current system. The low resistance of the water results in very low voltage drops with resultant low power costs and good current distribution. However, for satisfactory current distribution, the ratio of the distance from the anode to the near cathode, to the distance from the anode to the farthest cathodic area, should be relatively low. This ratio in the case of these sector gate units and fendering system is relatively high.

A study of possible anode locations on the sector gates and fendering for the navigation locks indicated that because of the necessity of placing the anodes near the face of the structures or within the gate or fendering structural members, shielding problems would be severe. It has been found that, in such cases, calcareous coatings build up on the high current density areas near the anodes, and tend to make the current distribute itself more evenly and thus protect remote areas. However, it has been found that even after the calcareous coatings have been built up on the near areas these areas still receive current. It is estimated that after the formation of the calcareous coatings on the near cathodic areas, that the ratio of current density between the near and far areas would be five to one. To get a current density of .005 ampere on the most remote cathodic area, it would be necessary for the system to maintain an average current density of .015 ampere over all protected surfaces. The power costs of a protection system of this magnitude would be significant.

During past courses on "Cathodic Protection", it has been recommended by personnel of the Rock Island District, that paint coatings are considered generally to be a necessary adjunct to a cathodic protection system on hydraulic structures.

For the aforementioned reasons, it was decided that a paint coating on underwater surfaces will be required.

(2) Paint Coating with Cathodic Protection. -

This method provides for the application of a relatively inexpensive paint coating such as Bitumastic No. 50 supplemented with cathodic protection. This method will require a relatively small amount of protection but a costly and extensive program of inspection and maintenance. As the paint deteriorates the cathodic protection will take over and protect the exposed metal. However, because of the rapid deterioration of paint coatings in salt water periodic inspection of the painted surfaces and renewal of paint coatings at all bare metal is a must to prevent the need for as much cathodic protection as for an unpainted structure.

(3) Coal Tar Epoxy Paint Coating with Cathodic Protection. -

This method is considered to be the most feasible for the navigation gates and fendering system. Experience with a similar method of cathodic protection provided the navigation gate for the New Bedford Hurricane Barrier located in New Bedford Harbor, Massachusetts, has shown that after more than 10 years in operation, the immersed portion of the gate exhibits no signs of corrosion. A discussion of the details of this method of corrosion control follows in Paragraph 5. below.

(4) Coal Tar Epoxy Paint Coating Without Cathodic Protection. -

Paint coatings tend to deteriorate rapidly in salt water and without the presence of cathodic protection to take over when deterioration begins, it will be necessary to scrape off the marine growth every few years to inspect the paint coatings. Damage to the paint coatings can be expected which will result in substantial maintenance including repainting at frequent intervals. This procedure is not desirable for the sector gates as it will require closure and dewatering of one of the locks with resultant interruption of boat traffic for a substantial period of time. Since the fendering system cannot be dewatered and checked for corrosion, the paint coating in itself is not considered satisfactory. As for the other steel structures immersed below water, they can either be dewatered or removed as necessary during normal maintenance inspection periods and the required work can be accomplished without affecting the operation of the facility.

From the above, it can be seen that cathodic protection in addition to the paint coatings will be required for the navigation lock sector gates and the steel fendering system. Coal tar epoxy coatings will suffice for all other steel structures immersed in water. A further description of the painting is discussed in Paragraph 5. below.

(5) Corrosion Resisting Alloy Iron Castings. -

Due to the high initial cost for these materials their use is generally not warranted except in those locations where cathodic protection is not practicable or extensive maintenance and inspection cannot be easily accomplished. In these locations, items such as pump propellers and shafts, and bulkhead slots, the use of the alloy iron castings or nickel-copper alloy is desired.

E. PROPOSED METHODS

5. Proposed Protection. -

a. Protective Coatings. - The following items which are immersed in water will be provided with near white metal blast cleaning, a prime coat of epoxy zinc-rich paint E-303 and a minimum of 2 coats of coal-tar epoxy (black) C-200 paint. The total thickness of the coatings will be at least 16 mils.

(1) Sector Gates

(2) Trash racks, stop logs and bulkheads

(3) Surfaces of pumps except the corrosion resisting alloy iron castings for propellers and the nickel-copper alloy for shafts.

(4) Sluice gates

(5) Intake screens for lock culverts

(6) Flange bolts for culvert valves

(7) Structural steel piling, bracing, miscellaneous ferrous metals in connection with permanent fenders and training walls and sheet piling in I walls

b. Cathodic Protection. - In addition to the coatings indicated above the sector gates and the navigation fendering will be provided with a galvanic cathodic protection system to protect the metal at possible holidays in the paint coating. The impressed current method of cathodic protection using eight separate systems was evaluated and found to work satisfactorily but had the disadvantages that impressed current cathodic protection systems require frequent inspections to make sure they are functioning properly and that if adjustments are improperly made and an overvoltage is applied, the paint coating could be severely damaged in as short a time as one month.

Therefore, a galvanic cathodic protection system will be required. The layout and details of the system are shown on Plates 2 and 3. Zinc anodes will be used as their voltage is adequate and there will be no danger of overvoltages damaging the paint. Magnesium anodes will not be used because their driving voltage in salt water will cause damage to paint coatings on the cathode areas adjacent to the anode. Zinc anodes will be procured in the segmented form with a 1/4-inch steel wire rope running through the middle of each segment and will be in accordance with Military Specification MIL-A-18001. The wire rope will be under the cathodic protection of the zinc.

A reasonably good paint coating will result in holidays of less than .1% of the total area. For the purpose of this design, holidays were assumed as 5% of total area.

c. Life Expectancy. -

It is expected that a good coating of coal tar epoxy with adequate cathodic protection will be in reasonably good condition 25 years from its application. As there is no available knowledge as to how much longer than 25 years a coal tar epoxy will be serviceable, it is assumed that all submerged metal parts will be repainted in 25 years. The original zinc anodes will be designed for a life expectancy to 10 years. If future inspections indicate that increased protection is necessary, magnesium anodes will be installed. Magnesium anodes may be satisfactorily used at that time, if deterioration of the coating justifies their use because with a higher anode current output there will be a higher voltage drop at the anode with a resultant lower voltage at the cathode surfaces.

F. CALCULATIONS

6. Criteria. -

Required current for polarization = .005 amperes per sq. ft. of base metal.
Zinc dissipation rate = 335 amp. hr./lb.
Make zinc anodes last 10 years.

ONE GATE LEAF	FACE PLATE Submerged Sq.ft.Area	FACE PLATE 5% Holiday Sq.ft.	FACE PLATE Minimum lbs.Zinc	Interior Submerged Sq.ft.Area	Interior 5% Holiday Sq.ft.	Interior Minimum lbs.Zinc
Large Gate Tide End	594	30	80	3071	154	402
" " Basin "	459	23	60	3700	185	484
Small " Tide "	203	11	29	956	48	126
" " Basin "	116	6	16	984	50	130

Typical Calculation

30 sq. ft. x .005 amperes/sq.ft. = .15 amperes

$$\frac{.15 \text{ amperes x } 24 \text{ hr/day x } 365 \text{ days/yr.}}{335 \text{ amp. hrs./lb.}} = \frac{(.15)x(8760)}{335} = 4 \text{ lbs/yr.}$$

4 x 10 years = 40 lbs x 2 to leave some remaining = 80 lbs.

Pile	Cross Section Area	Surface Area Length	Surface Area Sq. Ft.	5% Holiday	Min. lbs. Zinc
HP 10X42 Basin End	4.9 s.f./ft.	20	98	5	13
HP 10X42 Tide End	4.9 s.f./ft.	29	142	8	21
HP 12X53 Tide End	5.9 s.f./ft.	20	118	6	16

7. Anodes Required. -

Location	Face Plate No.	Face Plate Size (lbs)	Interior No.	Interior Size (lbs)
Large Lock (Tide End - 2 Leaves)	18	12	18	30
Large Lock (Basin End - 2 Leaves)	12	12	18	30
Small Locks (Tide End - 4 Leaves)	8	12	20	30
Small Locks (Basin End - 4 Leaves)	8	12	20	30
Fender A			25	30
Fenders B & C (Large Lock)			97	30
Total Anodes Required		46 @ 12 lb. =		552 lbs
		198 @ 30 lb. =		5,940 lbs
			Total	6,492 lbs

G. COST ESTIMATE

8. Cost Estimate. -

It is estimated that the cathodic protection system will cost $86,000. A summary of the costs which includes 10% each for overhead, profit, and contingencies, 6% for design and 7% for S & A, follows:

SUMMARY

Large Lock	$24,000
Small Locks	15,000
Fender A	11,000
Fender (Large Lock)	36,000
	$86,000

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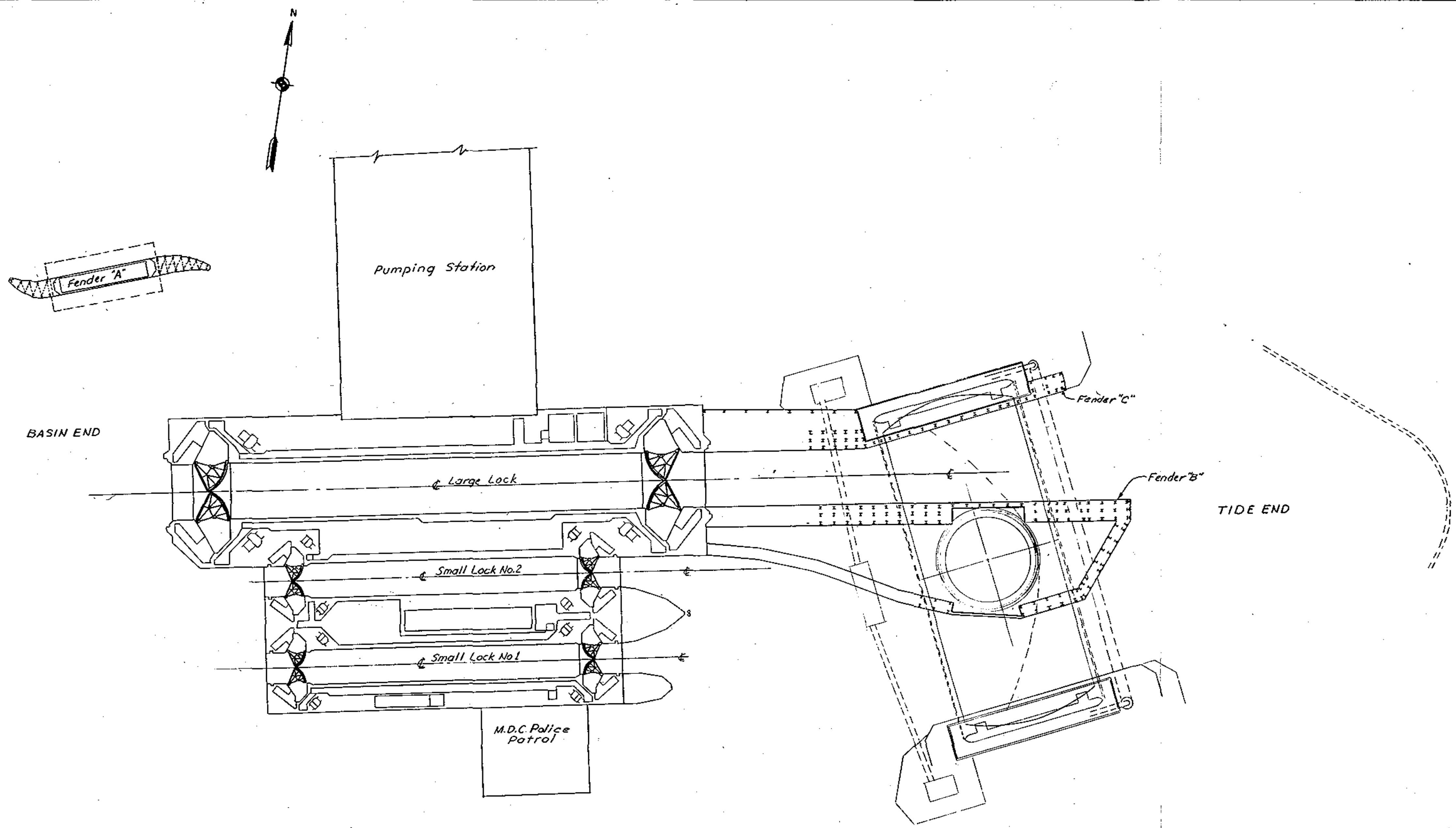

SITE CATHODIC PROTECTION PLAN

SCALE 1/32" = 1'- 0"

GRAPHIC SCALES
1/32" = 1'-0" 16' 0 16' 32' 64' 138' 276'

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED: CHIEF, SECTION
APPROVAL RECOMMENDED: CHIEF, TECH. ENG. BRANCH
REVIEWED: PROJECT ENGINEER
APPROVAL RECOMMENDED: CHIEF BRANCH

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
CATHODIC PROTECTION SYSTEM
SITE PLAN
CHARLES RIVER BASIN MASSACHUSETTS

APPROVED DATE
CHIEF, ENGINEERING DIVISION

SCALE | SPEC. NO.
DRAWING NUMBER
SHEET 1

PLATE IX-I

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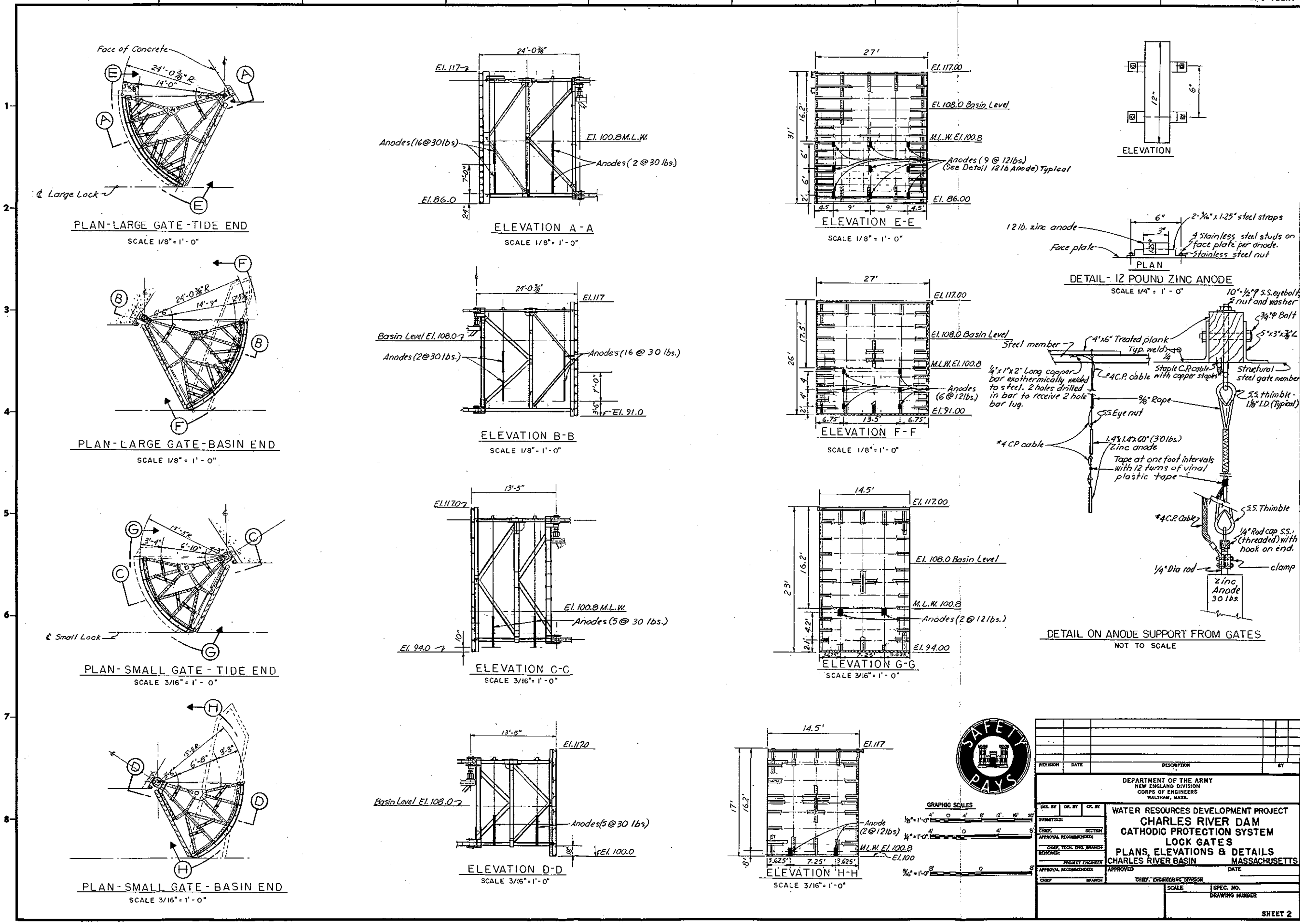

PLATE IX-II

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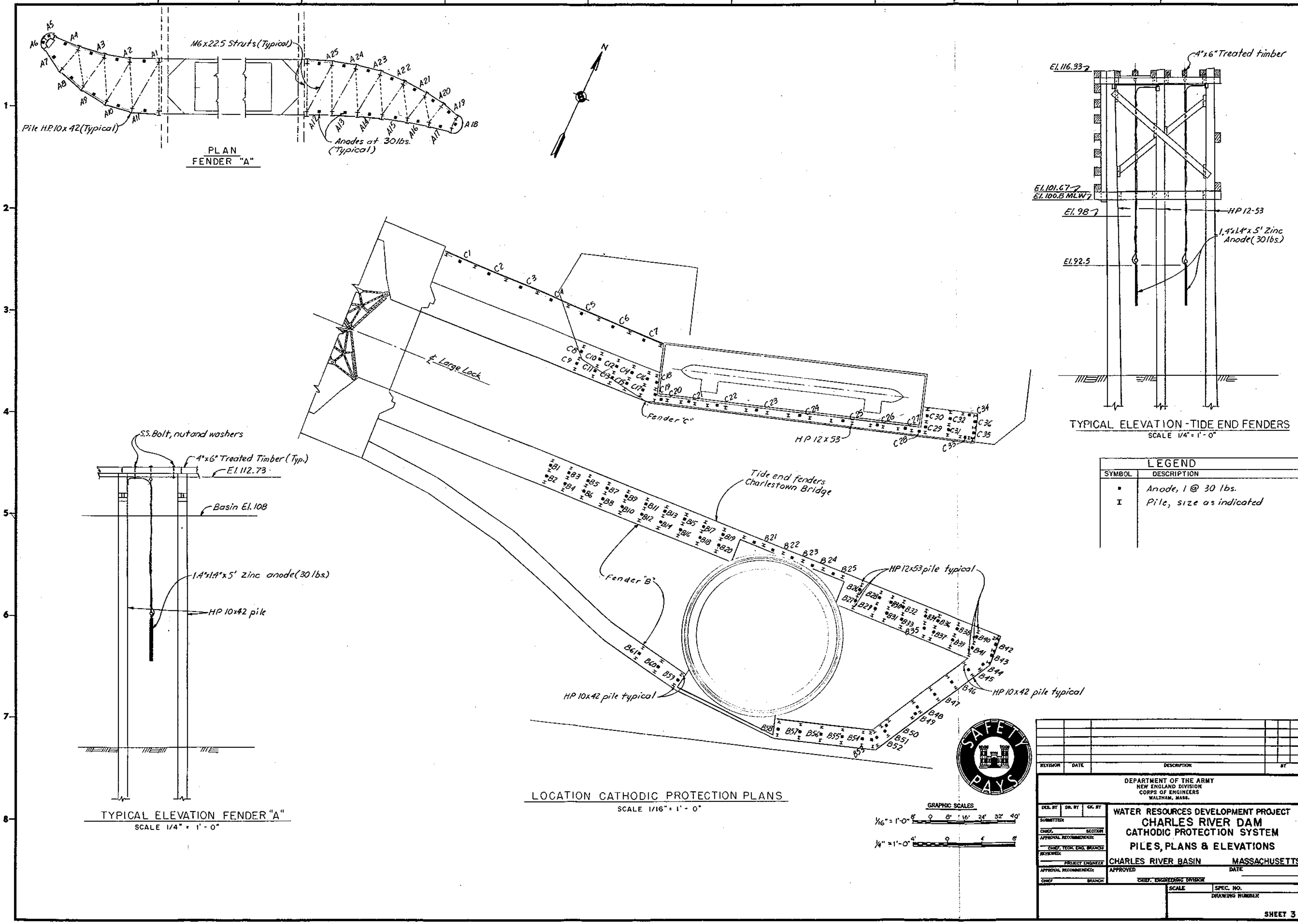

LEGEND

SYMBOL	DESCRIPTION
▪	Anode, 1 @ 30 lbs.
I	Pile, size as indicated

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
CHARLES RIVER DAM
CATHODIC PROTECTION SYSTEM
PILES, PLANS & ELEVATIONS
CHARLES RIVER BASIN MASSACHUSETTS

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, SECTION
APPROVAL RECOMMENDED:
CHIEF, TECH. ENG. BRANCH
REVIEWED:
PROJECT ENGINEER
APPROVAL RECOMMENDED:
CHIEF BRANCH
APPROVED DATE
CHIEF, ENGINEERING DIVISION
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET 3

PLATE IX-III